Novelty Journals

ISSN 2394-7349

International Journal of Novel Research in Engineering and Science
Vol. 12, Issue 2, pp: (56-65), Month: September 2025 - February 2026, Available at: www.noveltyjournals.com

Bamboo Derived Silicon-Carbon Particles Suitable for Renewable Energy Application

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DOI: https://doi.org/10.5281/zenodo.18297629

Published Date: 19-January-2026

Abstract: **Silicon particles was synthesized from bamboo leaf ash using a sol– gel and aluminothermic reduction techniques, while bamboo stem was carbonized through chemical activation to obtain porous carbon. The Silica gel was extracted from the bamboo leaf ash and was thereafter reduced to silicon via aluminothermic reduction by mixing the gel with aluminium powder in the ratio of 1:4. The mixture was then heated in a furnace and held at 650°C for 2 hours. After the reaction, the powder was immersed in 1M HCl solution for 6 hour to remove Al_2O_3 and unreacted Al powders. The synthesized materials were characterized using X-ray fluorescence (XRF) spectrometer, Fourier transform infrared (FTIR) spectrometer and scanning electron microscope (SEM). XRF analysis revealed that the bamboo leaf ash derived silica gel contained 83.67 wt% SiO_2, confirming its suitability as a precursor for silicon-based anodes. SEM/EDX micrographs showed that the bamboo-derived carbon particles exhibited a porous, interconnected morphology and 73.26 wt.% carbon while the silicon particulates synthesized from the silica contains 85.24 wt.%. The findings demonstrate that bamboo is a viable, sustainable dual precursor for the synthesis of silicon–carbon particles with promising structural and compositional features for LIB anode applications. This research contributes to the development of eco-friendly, low-cost, and high capacity materials for advanced energy storage system**

Keywords: **Sol-gel technique; Aluminothermic reduction; Bamboo leaf ash; Silica-gel; Silicon particles.**

1. INTRODUCTION

The rapid growth in global energy demand, coupled with environmental concerns arising from fossil fuel depletion and greenhouse gas emissions, has necessitated the transition towards renewable energy technologies and sustainable energy storage systems. While renewable energy sources such as solar and wind are increasingly being adopted, their intermittent nature presents significant challenges in ensuring a reliable power supply. To mitigate this, advanced electrochemical energy storage devices have become indispensable for modern energy infrastructure, particularly in portable electronics, electric vehicles (EVs), hybrid electric vehicles (HEVs), and grid-scale storage applications (Zheng *et al.*, 2018). Among various energy storage technologies, lithium-ion batteries (LIBs) have emerged as the most widely utilized due to their superior gravimetric and volumetric energy densities, long cycle life, low self-discharge, and high efficiency (Zhang *et al*., 2020). Since their commercialization in 1991, LIBs have undergone continuous improvements in design, chemistry, and performance. However, the increasing demands for higher capacity, faster charging rates, and improved safety especially in the electric mobility sector—necessitate further innovations in electrode materials, which fundamentally dictate the electrochemical performance of LIBs (Yue and Liang, 2017). Graphite, the conventional anode material for LIBs, has a theoretical specific capacity of only 372 mAh g^{-1}. Although adequate for low-power applications, this capacity is insufficient to meet the performance requirements of next-generation applications, particularly for EVs where high energy density and rapid charge-discharge capabilities are critical (Jiang *et al.*, 2018). In contrast, silicon (Si) has attracted tremendous research interest as an alternative anode material because of its ultrahigh theoretical capacity of 4,200 mAh g^{-1}, low discharge potential, and natural abundance (Wu *et al*., 2018). However, despite its advantages, Si suffers from severe drawbacks, including drastic volume expansion of ~300–400% during lithiation/delithiation, poor electrical conductivity, and unstable solid–electrolyte interphase (SEI) formation, which ultimately result in rapid capacity fading and electrode failure (Zhang *et al.*, 2016).

To address these limitations, recent research has focused on silicon–carbon (Si/C) composites, which combine the advantages of both materials. The carbon matrix provides mechanical support, buffers the volumetric expansion of Si, and improves electrical conductivity, while the silicon phase contributes high lithium storage capacity. Porous structures within these composites further promote electrolyte penetration, shorten lithium-ion diffusion pathways, and provide structural stability during charge–discharge cycling (An *et al*., 2019).

Despite progress, the large-scale application of Si/C composites is constrained by high production costs, energy-intensive synthesis processes, and the use of non-renewable raw materials. To address this, biomass-derived precursors have emerged as promising alternatives because they are abundant, renewable, low-cost, and environmentally friendly (Chen *et al*., 2020). Moreover, many biomass resources exhibit intrinsic hierarchical structures and chemical compositions advantageous for electrochemical applications.

Bamboo is particularly promising as a biomass precursor. It is one of the fastest-growing plants worldwide, with high carbon yield and silica-rich leaves. Bamboo stems can be carbonized into hierarchical porous carbon structures with large surface area and high conductivity, while bamboo leaves contain up to 80 wt.% silica, which can be extracted and reduced to silicon through aluminothermic or magnesiothermic reduction (Silviana and Bayu, 2018; Olawale, 2020). By integrating bamboo-derived silica and carbon, porous Si/C composites can be synthesized with synergistic properties that improve lithium storage capacity, conductivity, and cycling stability (Yan *et al*., 2018).

Therefore, this study investigates bamboo-derived porous silica-carbon composites as potential anode materials for LIBs. This approach not only addresses the limitations of conventional graphite and pure silicon anodes but also promotes sustainable utilization of bamboo, an underutilized agrowaste resource, aligning with global drives toward renewable energy and sustainable materials engineering.

2. MATERIALS AND METHOD

MATERIALS

Bamboo leaves and bamboo stem were used in the work for the synthesis of silicon and carbon particles respectively. The raw bamboo leaves and bamboo stem were collected from Apatapiti Layout, FUTA south-gate, Akure, Ondo State, Nigeria. Sodium hydroxide (NaOH) and hydrochloric acid reagent, used for the sol-gel process and were procured from Pascal Scientific Limited, Akure, Ondo State. Microporous polymeric film, polyvinylidene fluorides, potassium hydroxide, copper foil, filter papers, and distilled water were also procured from Pascal Scientific Limited, Akure, Ondo State.

METHODS

EXTRACTION OF SILICA GEL FROM BAMBOO LEAVES

Silica was extracted from Bamboo Leaves Ash (BLA) using the sol–gel technique to produce silica gel. The processes involve alkaline dissolution of amorphous silica (mainly SiO_2) into sodium silicate (Na_2SiO_3) followed by acidification to form silicic acid (hydrolysis), then gelation (condensation) into a silica gel, and drying. To obtain BLA, the bamboo leaves were washed in water and dried in an oven at 80°C for 24 hours to remove moisture content. They were then fed into an enclosed drum and burnt to ash. The ash was conditioned in a muffle furnace at a temperature of 650ºC for 3 hours. One hundred milliliters (100 ml) of 2 M NaOH was added to 10 g of BLA and the mixture was boiled for 1 hour with constant stirring with the aid of a magnetic stirrer to extract silica and produce sodium silicate solution. The solution was filtered using Whatman ashless filter paper No. 41. The filtrate solution was cooled to room temperature and its pH was being reduced to 7.0 with concentrated HCl under constant stirring to produce silica gels. The gel formed was aged for 18 hours. After aging, the soft gel was gently broken by adding 100 ml of distilled water and centrifuged at 3000 rpm to make a slurry.

ISSN 2394-7349

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The slurry was filtered and washed, after which the gel was dried at 100°C for 12 hours to produce white powder silica particulates.

The chemical reactions involve in the sol-gel process are stated in equations 1-5

Calcination of Bamboo leaves

Dried Bamboo leaves + $O_2 \rightarrow CO_2(g) + H_2O(g) + SiO_2(p)$ + Other Ash (1)

Alkaline Extraction (Dissolution)

$SiO_2(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O$ (2)

Acidification & Gelation (Sol-Gel Steps)

$Na_2SiO_3(aq) + 2HCl(aq) \rightarrow H_2SiO_3(s/gel) + 2NaCl(aq)$ (3)

Condensation of the silicic acid to form a silica network (gel)

$Si\text{-}OH + HO\text{-}Si \rightarrow Si\text{-}O\text{-}Si + H_2O$ (4)

Drying of the silica gel

$SiO_2 \cdot nH_2O(gel) \rightarrow SiO_2(powder) + nH_2O(g)$ (5)

The extraction processes of the silica particulates showing the pictorial view of the various stages are presented in Figures 1-2

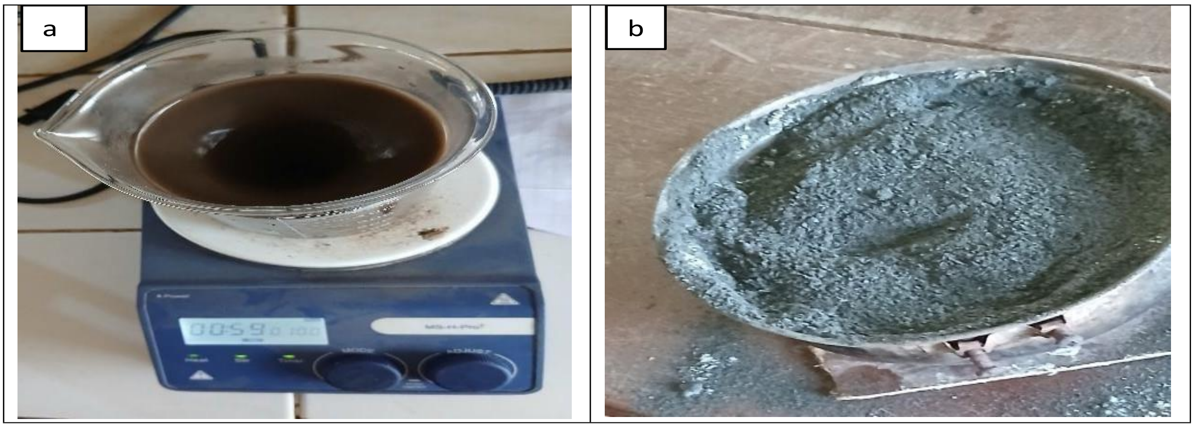

Figure 1(a) Boiling and stirring process with the use of a magnetic stirrer (b) An image of the conditioned bamboo leaves ash

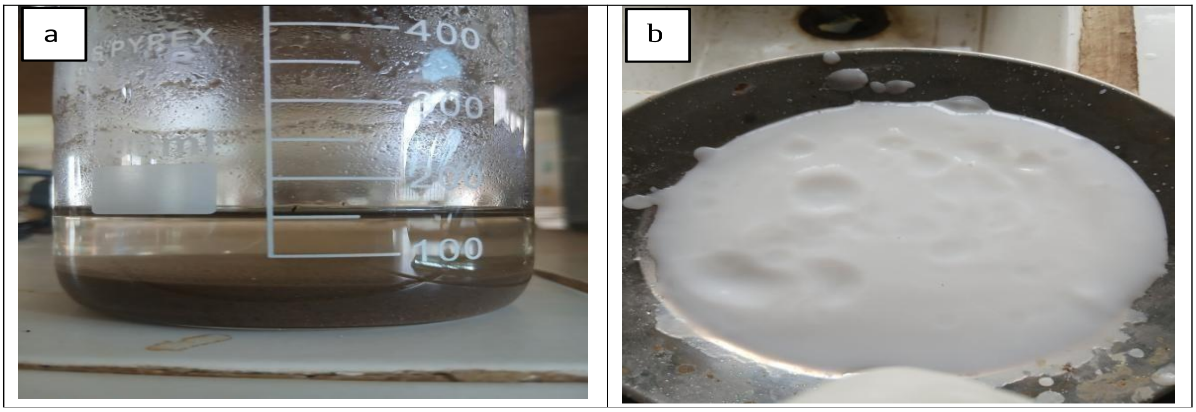

Figure 2: (a) An image of the filtered precipitate of the boiled bamboo leave ash with NaOH and (b) Extracted silica gel

SYNTHESIS OF SILICON PARTICLES FROM THE SILICA GEL

The extracted silica-gel from the BLA was reduced to silicon via aluminothermic reduction by mixing the gel with aluminium powder in the ratio of 1:4. The mixture was then heated in a furnace and held at 650°C for 2 hours. After the reaction, the powder was immersed in 1M HCl solution for 6 hour to remove Al_2O_3 and unreacted Al powders. The primary reaction for the aluminothermic reduction of silica is presented in equation 6

$$3SiO_2(s) + 4Al(s/l) \rightarrow 3Si(l) + 2Al_2O_3(s) \quad (6)$$

SYNTHESIS OF BAMBOO DERIVED CARBON MATERIALS

Bamboo stems were collected from Apatapiti layout, Akure and were first cut into bamboo strips (length: 5 mm; width:3mm; thickness:0.5 mm) using a penknife. The bamboo strips were cleaned with distilled water and alcohol before being dried at 100°C in the oven for 24 hours prior to further processing. The dried bamboo strips were directly mixed with KOH (w/w = 1:4) and stirred for 1 hour. After the addition of 20 ml distilled water, the solution was being heated to 80°C with stirring for 5 hours and then dried in an oven at 100°C for 24 hours. The mixture was subsequently transferred to a muffle furnace and it was annealed at 600°C for 30 minutes at a heating rate of 5°C min^{-1}. After treatment, the residue was washed with 1 M HCl solution and distilled water until the pH was neutral (pH = 7). Finally, the washed product was dried in an oven at 100°C for 12 hours and was then fully ground into fine particles.

CHARACTERIZATION OF SILICA AND CARBON PARTICLES

X-ray fluorescence spectroscopy, a non-destructive analytical technique was used to determine the chemical composition of the obtained silica particulates. The SEM/EDX characterization of the silicon and carbon particulates was carried out to determine their elemental composition using an AURIGA Scanning Electron Microscope (SEM) (Carl Zeiss, Germany) attached with Energy Dispersive X-ray Spectrometer with an accelerating voltage of 15 kV.

3. RESULT AND DISCUSSION

The results of the elemental composition, the morphology and the chemical composition of the BLA derived silica particulates, bamboo derived carbon and silicon particulates are as presented in Tables 1 to 2, and Figures 3 to 6.

MORPHOLOGICAL AND ELEMENTAL COMPOSITION OF THE BLA DERIVED SILICA

The morphological and elemental characteristics of the silica extracted from Bamboo Leaf Ash (BLA) were evaluated using Scanning Electron Microscope (SEM) and Energy Dispersive X-ray Spectrometer (EDS). The analysis provides critical insights into the quality and suitability of the extracted material for subsequent processing into a silicon-based anode. The SEM micrograph reveals an irregular and highly agglomerated morphology with a flaky, porous structure. This is characteristic of silica xerogels produced via the sol-gel method, where the liquid phase is removed under normal conditions, leading to the collapse of the gel network and the formation of a dense, particulate solid (Wang *et al*., 2019). The observed porosity and high surface area of the agglomerates are advantageous for battery applications, as such a structure can facilitate better electrolyte wetting and provide a reactive template for the subsequent metallothermic reduction to silicon.

The EDS analysis confirms the presence of silicon and oxygen the major elements, with a weight concentration of 68.16 wt.% and 21.57 wt.% respectively. Carbon was also present with a value 6.12 wt.% .This confirms the successful extraction of a silica-rich material from the bamboo leaves. The presence of the carbon content is a common feature in biomass-derived ashes, resulting from the incomplete combustion of organic compounds (lignin and cellulose) present in the plant material (Yan *et al.*, 2018). The minor presence of potassium and chlorine is also typical, as these are inherent alkali and halogen elements in plant tissues that can persist through the combustion and acid leaching processes.

The detection of impurities such as Aluminium (Al: 1.85 wt.%), (Ca: 1.69 wt.%) and Iron (Fe: 0.61 wt.%) can be attributed to the natural mineral content (ash composition) of the bamboo leaves and potential minor contamination from processing equipment. The presence of these metallic impurities is a well documented challenge in the utilization of biomass-derived materials for high-performance electrochemical applications. As highlighted by Wang *et al*. (2019) in their study on bamboo leaf derived silicon, such impurities can detrimentally affect the electrochemical performance of the final anode material by reducing electrical conductivity and promoting irreversible side reactions with the electrolyte. Therefore, the effectiveness of the subsequent aluminothermic reduction and the rigorous acid leaching steps will be critical to removing these impurities and obtaining a high purity silicon product.

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The compositional profile observed in this work is consistent with findings in the literature for similar biomass precursors. Yan *et al*. (2018) noted that materials derived from bamboo inherently contain various heteroatoms. The key to leveraging this sustainable precursor lies in the optimization of purification and reduction protocols. The porous morphology observed via SEM is, in fact, beneficial for these subsequent steps, as it provides a high surface area for the aluminothermic reduction reaction, potentially leading to more efficient conversion of silica to elemental silicon.

The SEM Image and EDX result of the BLA derived silica are presented in Figure 3.

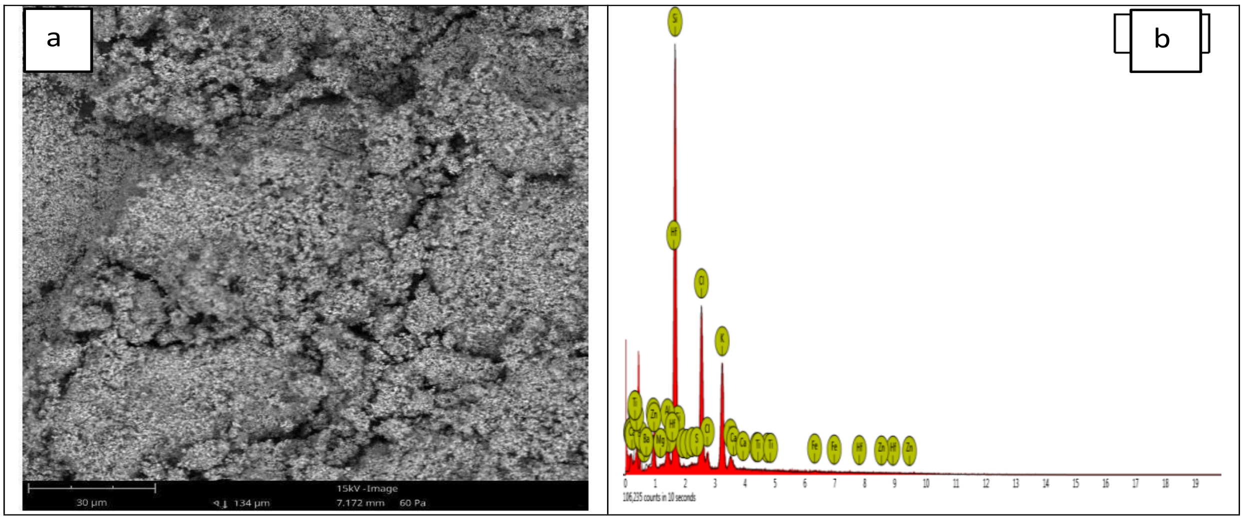

Figure 3: (a) SEM Image of the BLA derived silica (b) EDX of the BLA derived silica

X-RAY FLUORESCENCE ANALYSIS OF THE BLA DERIVED SILICA

X-ray Fluorescence (XRF) analysis was conducted to determine the precise chemical composition of the silica extracted from Bamboo Leaf Ash (BLA). The results, presented in oxide form in Table 1 provide a quantitative assessment of the purity and impurity profile of the material, which is critical for evaluating its suitability as a precursor for silicon production. The analysis confirms that the extracted material is silica-rich, with silicon dioxide (SiO_2) being the major component at a concentration of 83.67 wt%. This significant silica content validates the effectiveness of the sol-gel extraction process from bamboo leaves and is consistent with values reported in the literature for similar biomass sources. For instance, studies on bamboo leaves have consistently reported silica contents in the range of 70-80 wt% in the ash (Olawale, 2020; Yan *et al*., 2018). The slightly higher value obtained in this work (83.67%) can be attributed to the absence of un-burnt carbon and other non-volatile impurities that were entirely removed during the combustion and acid leaching stages. This aligns with the low carbon and other elemental impurities observed in the EDS analysis. A notable feature of the XRF spectrum is the presence of potassium oxide (K_2O) at 5.864 wt% and magnesium oxide (MgO) at 4.123 wt%. The presence of these alkali and alkaline earth metal oxides is characteristic of plant-derived materials. Potassium is a ubiquitous nutrient in plants, and its high concentration in the ash is expected (Wang *et al*., 2019). Similarly, magnesium is a core component of chlorophyll, explaining its significant residue after combustion. While these impurities confirm the botanical origin of the silica, they pose a challenge for battery applications in they very high in concentration. Alkali metals like potassium can lead to undesirable side reactions within the battery cell, potentially compromising the stability of the solid-electrolyte interphase (SEI) and causing capacity fade. Other minor impurities detected include alumina (Al_2O_3) at 1.761 wt%, calcium oxide (CaO) at 0.463 wt%, and iron oxide (Fe_2O_3) at 0.454 wt%. These typically originate from the soil in which the bamboo was grown and are incorporated into the plant's structure. The presence of these metallic impurities in little concentration will overcome a common challenge in utilizing biomass for high performance materials, as highlighted by Wang *et al.* (2019). They noted that residual metallic compounds in high concentration could act as inert phases, reducing the overall electrochemical activity of the final silicon product and impairing electrical conductivity.

Table 1: Chemical composition of the BLA derived silica via XRF

Compound	SiO_2	Fe_2O_3	CaO	MgO	K_2O	Al_2O_3	TiO_2	SnO_2
Weight %	83.67	0.454	0.463	4.123	5.864	3.761	0.110	1.555

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FOURIER TRANSFORM INFRARED SPECTROSCOPIC ANALYSIS OF BLA DERIVED SILICA

The Strong absorption at ~1025–1030 cm⁻¹ is the most prominent feature of the spectrum and corresponds to asymmetric stretching vibrations of Si–O–Si bonds. The strong intensity of this peak confirms that silica (SiO_2) is the major constituent of the bamboo leaf ash. Its position near 1026 cm⁻¹ is characteristic of amorphous silica, rather than crystalline quartz.

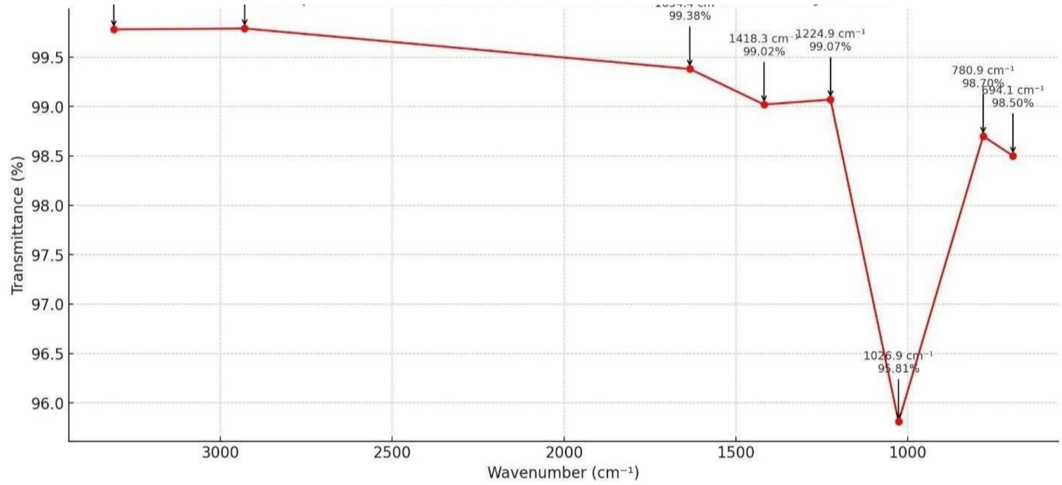

Figure 4: Fourier Transform Infrared Spectrum of BLA Derived Silica

MORPHOLOGY AND ELEMENTAL COMPOSITION OF THE BAMBOO DERIVED SILICON PARTICULATES

The SEM micrograph of the synthesized silicon particulates from the silica gel at 500× magnification as presented in Figure 6a shows that the bamboo-derived silicon particles exhibit:Irregular, angular particle morphology with rough surfaces, indicating fragmentation during combustion, calcination, and post-processing steps. Agglomerated structures, where smaller particles adhere to larger ones. This agglomeration is typical for silica particles derived from biomass due to high surface energy and the presence of surface silanol (Si–OH) groups.Porous and textured surfaces, which are characteristic of biogenic silica and beneficial for applications requiring high surface area, such as adsorption or catalysis. Overall, the SEM results indicate that the bamboo-derived silicon particles are non-spherical, porous, and microstructured, consistent with ash-derived amorphous silica.

The EDS graph of the silicon particulates identifies elements such as silicon (Si: 85.24 wt.%), sodium (Na: 5.46 wt%), chlorine (Cl: 5.18 wt.%), and potassium (K: 4.12 wt%). The presence of silicon is expected, as the focus is on bamboo-derived silicon particles. The other elements may indicate impurities or the presence of minerals within the bamboo.

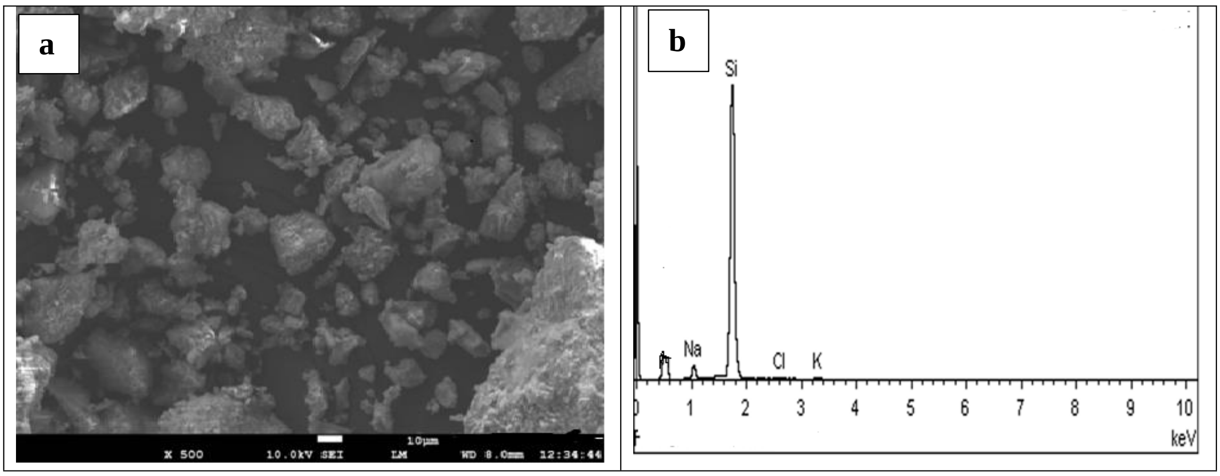

Figure 5: (a) SEM Image of BLA derived silicon particulates by aluminothermic technique and (b) EDX of silicon particulate

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MORPHOLOGY AND ELEMENTAL COMPOSITION OF THE BAMBOO DERIVED CARBON

The structural morphology and elemental composition of the carbon material synthesized from bamboo stems were characterized using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). The results are crucial for assessing the quality of the porous carbon as a conductive matrix for the silicon-carbon composite anode. The SEM image of the bamboo derived carbon and EDX spectrum of the bamboo derived carbon is presented in Figure 6 while the elemental composition of carbon particles is presented in Table 2.

The SEM micrograph reveals a highly porous and irregular morphology with a flaky, interconnected network. This structure is characteristic of activated carbons produced from lignocellulosic biomass via chemical activation with KOH. The visible pores and crevices are a direct result of the KOH activation process, which etches the carbon framework, creating a high surface area. As demonstrated by Yan *et al*. (2018), such a hierarchical porous structure in Bamboo derived carbon is highly desirable for battery applications. The pores can serve as channels for efficient electrolyte ion transport and, most importantly, as void space to accommodate the significant volume expansion of silicon during lithiation, thereby enhancing the cycling stability of the composite anode.

The EDX analysis provides the elemental composition of the material. Carbon (C) is the dominant element, with a high atomic weight of 73.26% confirming the successful carbonization of the bamboo stem. However, the presence of significant impurities is evident. Potassium (K: 12.57 wt%) and Chlorine (Cl: 9.27 wt%) are the most prominent contaminants. The high potassium content is a direct residue from the KOH chemical activation agent used in the synthesis process, indicating that the subsequent washing steps, while sufficient to neutralize the pH, were not exhaustive enough to remove all potassium compounds trapped within the porous structure. The presence of chlorine likely originates from the hydrochloric acid (HCl) used during the washing step. Other elements detected include Nitrogen (N: 9.14 wt%), which may originate from proteins in the bamboo biomass, and Aluminium (Al: 6.62 wt%), which could be an environmental contaminant or from the soil. The presence of silicon (Si: 3.44 wt%) is expected, as bamboo stems naturally contain silica phytoliths. The existence of these impurities, particularly potassium, is a double-edged sword. On one hand, the residual KOH activation agent is responsible for creating the beneficial porous morphology seen in the SEM image. On the other hand, for lithium-ion battery applications, these metallic impurities (K, Al) can be detrimental. They may participate in irreversible reactions with the electrolyte, leading to poor coulombic efficiency and capacity fading, as noted in studies carried out by Chen *et al.* (2020) on biomass-derived carbons. The presence of these elements underscores the importance of optimizing the post-activation washing protocol to maximize carbon purity while preserving the porous architecture.

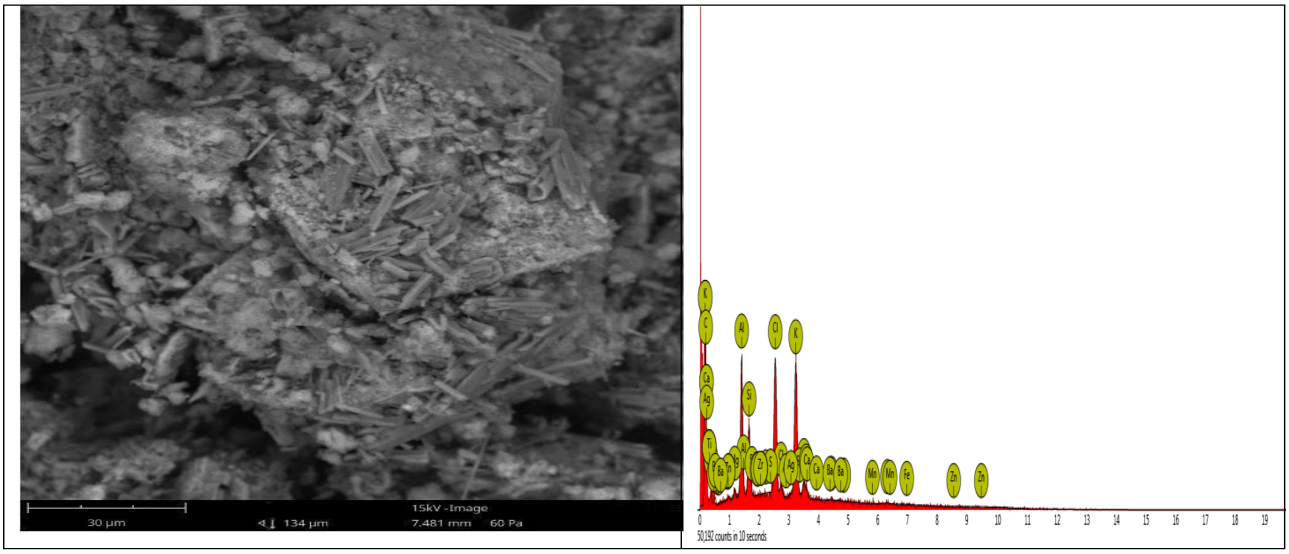

Figure 6: (a) SEM image of the bamboo derived carbon (b) EDX image of the bamboo derived carbon.

Table 2. Elemental composition of the bamboo derived carbon via EDX

Element	Atomic Concentration %	Weight Concentration %
C	73.26	55.17
K	5.13	12.57
Cl	4.17	9.27
N	10.40	9.14
Al	3.91	6.62
Si	1.95	3.44
Sn	0.19	1.43
Ca	0.29	0.73
Mg	0.29	0.44
Fe	0.12	0.42
Ti	0.04	0.13
S	0.00	0.0015
P	0.00	0.003
Zn	0.00	0.004
Zr	0.00	0.006
Ba	0.00	0.003

FOURIER TRANSFORM INFRARED (FTIR) SPECTROSCOPY ANALYSIS OF BAMBOO DERIVED CARBON PARTICULATES

Fourier Transform Infrared (FTIR) spectroscopy was used to identify the various functional groups present on the surface of the bamboo stem derived carbon particulates. The FTIR of the Bamboo-Derived Carbon Particles is presented in Figure 7 The FTIR spectrum of the bamboo-derived carbon particles (4000–1000 cm^{-1}) provides clear evidence of surface functional groups that originate from bamboo's lignocellulosic structure and its transformation during carbonization.

The broad absorption observed around 3600–3200 cm^{-1} is attributed to O–H stretching vibrations. This indicates the presence of hydroxyl groups from phenolic, alcoholic, or carboxylic functionalities, as well as adsorbed moisture. In bamboo-derived carbon, such groups typically remain due to incomplete dehydration of cellulose, hemicellulose, and lignin, or are introduced during post-treatment/activation. These hydroxyl groups enhance surface polarity and adsorption capability.

Small features near 3000–2850 cm^{-1} correspond to aliphatic C–H stretching vibrations ($–CH_2$ and $–CH_3$). Their relatively low intensity suggests that most aliphatic components were decomposed during carbonization, leaving behind a predominantly carbonaceous structure with minor residual hydrocarbon chains.

The peaks around 2400–2300 cm^{-1} are commonly associated with CO_2 asymmetric stretching or atmospheric CO_2 trapped during measurement. These are not intrinsic to the carbon structure but are often observed in FTIR spectra of porous carbons.

The Band near 1700–1600 cm^{-1} indicates C=O stretching of carbonyl or carboxyl groups and/or C=C stretching of aromatic rings. The presence of these bands confirms the formation of aromatic carbon domains typical of biochar and activated carbon, originating from lignin aromatization during thermal treatment while the peaks around 1500–1400 cm^{-1} can be assigned to aromatic C=C vibrations and C–H bending modes. Their appearance further supports the development of an aromatic carbon framework in the bamboo-derived carbon particles.

The Strong absorption between 1300–1000 cm^{-1} corresponds to C–O stretching vibrations of alcohols, phenols, ethers, or ester groups. These functionalities are characteristic of biomass-derived carbons and indicate oxygen-containing surface groups that are beneficial for applications such as adsorption, catalysis, and electrochemical energy storage.

The FTIR spectrum confirms that bamboo-derived carbon particles possess a partially graphitized aromatic backbone decorated with oxygen-containing functional groups (–OH, C=O, C–O). This combination reflects successful carbonization of bamboo while retaining surface chemistry that enhances reactivity, wettability, and adsorption performance.

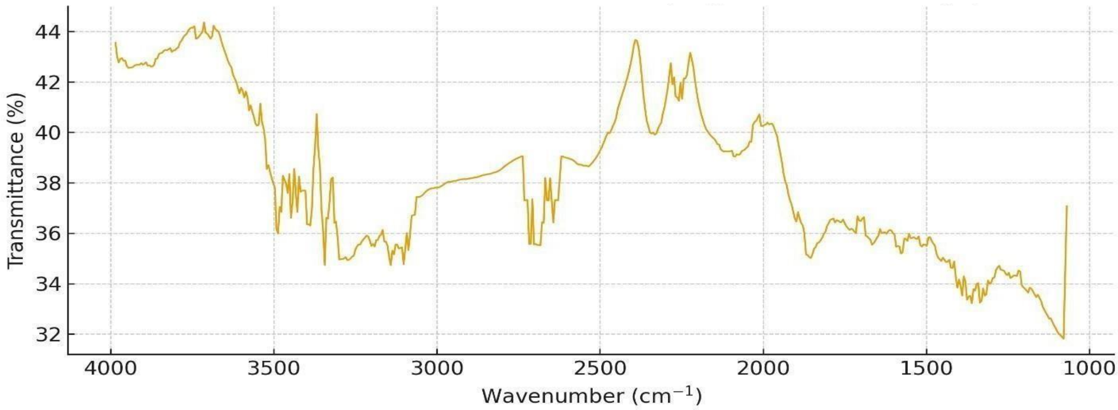

Figure 7: FTIR of Bamboo-Derived Carbon Particles

4. CONCLUSION

This study successfully demonstrated the feasibility of using bamboo as a sustainable dual precursor for silicon-carbon composite materials for lithium-ion battery anodes. Silica particulates was effectively extracted from bamboo leaves and was latter reduced to silicon particulates by aluminothermic reaction. A porous carbon matrix was synthesized from bamboo stems. Characterization of the silica using XRF spectrometer confirmed that the extracted particulate was rich in silica (SiO_2) with a value of 83.67 wt%) with a porous morphology. The EDS result of the silicon particulates contains 85.24 wt. % . The SEM/EDS of the carbon material exhibited a highly porous structure, 73.26 wt.% and ideal for buffering volume changes in a composite anode.

AUTHOR'S CONTRIBUTIONS:

OOD, HKT, OTO, AFA, OGO, EOO wrote the main manuscript text and, OOD, HKT, OTO, AFA, OGO, EOO prepared figures. All authors reviewed the manuscript

ACKNOWLEDGEMENT:

The authors acknowledged the financial support received from Tertiary Education Trust Fund (TETFund) through Institution Based Research (IBR) intervention, with reference number, TETF/DR&DICE/UNI/AKURE/IBR/2024/VOL.I

CONSENT FOR PUBLICATION: All authors agreed upon the current version of submission for publication. Data availability: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

ETHICAL APPROVAL: Not applicable.

CONFLICT OF INTERESTS: The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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